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(54) Title: PROGRAMMABLE MATCHED FILTER FOR SPREAD SPECTRUM
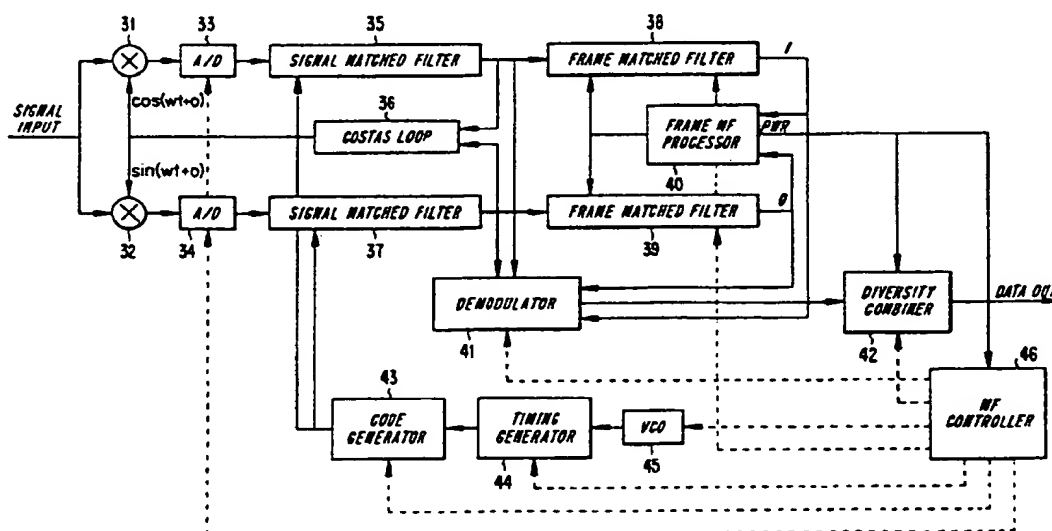
(57) **Abstract**

A spread-spectrum matched filter apparatus includes a code generator (43), an in-phase programmable-matched filter (I-PMF) (35), a quadrature programmable-matched filter (Q-PMF) (37), an in-phase frame-matched filter (I-FMF) (38), a quadrature frame-matched filter (Q-FMF) (39) and a controller (46). The code generator (43) alternately generates replicas of pilot and data chip-sequence signals that are used to set the impulse responses of the I-PMF (35) and the Q-PMF (37), which are thus alternately set up to detect pilot or data spread-spectrum channels. The I-FMF (38) and the Q-FMF (39) detect a despread pilot bit sequence signal and generate a peak-pilot correlation signal used by the controller (46) to determine when to change the impulse responses of the PMFs (35, 37).

## PROGRAMMABLE MATCHED FILTER
### FOR SPREAD SPECTRUM

### BACKGROUND OF THE INVENTION

This invention relates to spread spectrum communications, and more particularly to a programmable matched filter which can be used for despreading a pilot-chip-code-sequence signal and a message-chip-code-sequence signal.

### DESCRIPTION OF THE RELEVANT ART

Spread spectrum communications require that an incoming spreading chip-code sequence embedded in a spread-spectrum signal, and the local spreading chip-code sequence at a receiver, be phase synchronized prior to processing of information transfer. Phase synchronization of the spreading chip code sequences is commonly known as code acquisition. Code acquisition is one of the most difficult issues facing the system designer.

Code acquisition is followed by the tracking process. Due to imperfect frequency references the incoming spreading chip-code sequence and the local spreading chip-code sequence tend to lose phase synchronization. Retaining the phase synchronization, or tracking, is a difficult process that typically employs feedback loops.

Conventional spread-spectrum systems implemented without the benefit of a matched filter employ additional circuits, such as delay locked loops (DLLs) dedicated to achieving and sustaining fine grained phase synchronization between the local spreading code and the incoming spreading

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code to within a unit of time which is less than the
duration of one signal sample.  The circuits for sustaining
fine grain phase synchronization are difficult to design and
implement.

5       In wireless environments, minimizing the performance
degradation due to long or short duration attenuation of the
incoming signal caused by changing propagation channel
conditions is highly desirable.  As the quality of the
channel degrades, the quality of the detected signal
10      degrades, often below acceptable levels.

        Typical systems combat this condition by employing any
of a variety of techniques collectively known as diversity
processing.  The diversity processing techniques have in
common the ability to independently manipulate the
15      information received through separate propagation paths, or
channels, independently.  The benefit from diversity
processing is that when a given propagation channel
degrades, the information can be recovered from signals
received via other channels.  A common though suboptimum,
20      diversity technique is to employ two or more separate
antennas and process the signal via two or more processing
chains in parallel.  Although necessary, the use of two or
more antennas and processing is a difficult and costly
undertaking, requiring two or more times the number of
25      circuits required for one path as well as additional
circuits and processing for insuring that the individual
channel outputs are synchronized.  A better approach is to
employ a wideband signal of bandwidth W.  If the multipath

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spread were $T_M$ then the receiver can recover $L=T_M(W+1)$
replicas of the incoming signal. If the receiver properly
processed the replicas, then the receiver attains the
performance of an equivalent $L^{th}$ order diversity

5      communication system. For wideband systems the value of L
can become very large and it becomes unfeasible to implement
L processing paths. Thus a non-matched filter receiver can
not attain the best possible performance.

       The coherent demodulation of information signals

10     requires that the phase of the carrier, at the radio
frequency (RF), intermediate frequency (IF) or other
frequency at which the demodulation is to take place, be
known. The extraction of the phase of the carrier
information requires that additional feedback loops be

15     employed, such as phase-locked loops (PLLs), Costas loops,
$n^{th}$ power loops or other devices capable of extracting the
carrier phase information. In the wireless environment,
where signals propagate through a multitude of separate and
independent channels, each path processed by the receiver

20     requires its own carrier phase information and therefore its
own means to extract it. This requirement greatly increases
the potential complexity of the system. The need to limit
system complexity acts so as to limit the system
performance.

25     Conventional receivers, for spread-spectrum reception
or other coherent systems, employ circuits dedicated to
extracting the carrier phase. These techniques, e.g.,
phase-locked loops (PLLs), Costas loops, $n^{th}$ power loops,

etc., exhibit design and implementation complexities that
are well documented throughout the professional literature.
A separate and independent set of these circuits is
implemented for each individual signal path, or channel,

5      that is received.  Practical limits on system complexity
force the system to receive a small subset of the $L=T_M(W+1)$
independent signal replicas.  Typically up to three such
circuit sets can be practically implemented and thus only up
to three independent signal replicas can be received and

10     processed.

A complex matched filter consists of two identical
branches, in-phase (I) and quadrature (Q), used to process
in-phase and quadrature signals.  Each branch consists of a
local signal reference register, an incoming signal

15     register, a multiplication layer and an adder tree.  The
multiplication layer and the adder tree contained in the in-
phase and quadrature branches are identical and may contain
the majority of the gates used to implement the matched
filter.  To implement a matched filter it is preferable to

20     reduce the size of the structure as much as possible.

Processing multiple signals, whether QPSK or BPSK
modulated, simultaneously by matched filtering is desirable.
An example of a requirement for processing multiple signals
is the simultaneous matched filter processing of a data

25     signal and a pilot signal, from a spread-spectrum signal
combining such signals.  This normally requires the
implementation of two or more matched filter structures, one
per signal.  Matched filters are large and difficult

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structures to build.  Thus, limiting the size and complexity
of the devices as much as possible is desirable.


## SUMMARY OF THE INVENTION

A general object of the invention is a spread-spectrum
5       receiver which reduces cost and circuit complexity, reduces
the volume required and improves the performance, i.e.,
acquisition time, of conventional spread-spectrum chip-
sequence signal acquisition.

Another object of the invention is a spread-spectrum
10      receiver which has improved bit-error-rate (BER) performance
over conventional coherent demodulation techniques, methods
and circuits.

An additional object of the invention is to reduce cost
and circuit complexity, reduce the volume required and
15      improve the performance of conventional diversity reception,
separation and combining techniques, methods and circuits.

A further object of the invention is to reduce the
complexity associated with the simultaneous matched filter
processing of multiple signals.

20      A still further object of the invention is to reduce
the size and complexity associated with the implementation
of complex in-phase matched filters and quadrature-phase
matched filters.

According to the present invention, as embodied and
25      broadly described herein, a spread-spectrum-matched-filter
apparatus is provided including a code generator, a
programmable-matched filter, a frame-matched filter, and a

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controller. The code generator is coupled to the
programmable-matched filter and to the controller. The
frame-matched filter is coupled to the output of the
programmable-matched filter.

5         The spread-spectrum-matched-filter apparatus can be
used as part of a spread-spectrum receiver, for receiving a
received spread-spectrum signal. A received spread-spectrum
signal, as used herein, is a spread-spectrum signal arriving
at the input of the spread-spectrum receiver. The received
10        spread-spectrum signal is assumed to include a pilot-spread-
spectrum channel and a data-spread-spectrum channel. The
pilot-spread-spectrum channel is generated from spread-
spectrum processing a pilot-bit-sequence signal with a
pilot-chip-sequence signal. The data-spread-spectrum
15        channel is generated from spread-spectrum processing a data-
bit-sequence signal with a data-chip-sequence signal.

          The code generator generates a replica of the pilot-
chip-sequence signal and a replica of the data-chip-sequence
signal. The programmable-matched-filter has a programmable-
20        impulse response which can be matched to a pilot-spread-
spectrum channel or the data-spread-spectrum channel of the
received spread-spectrum signal. The replica of the data-
chip-sequence signal generated by the code generator is used
to set or match the programmable-impulse response of the
25        programmable-matched filter to the data-chip-sequence signal
embedded in the received spread-spectrum signal. When
matched, upon receiving the received spread-spectrum signal
having the data-spread-spectrum channel embedded herein, the

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programmable-matched filter can detect and output a data-bit-sequence signal.

The replica of the pilot-chip-sequence signal generated by the code generator can set the programmable-impulse response of the programmable-matched filter to be matched to the pilot-chip-sequence signal embedded in the received spread-spectrum signal. With this setting, the programmable-matched filter can detect and output a despread-pilot-bit-sequence signal.

The frame-matched filter has a frame-impulse response which is matched to the pilot-bit-sequence signal. Accordingly, the frame-matched filter filters the despread-pilot-bit-sequence signal and generates, as an output, a peak-pilot-correlation signal in response to the despread-pilot-bit-sequence signal matching the frame-impulse response.

The controller controls to which of the programmable-impulse responses the programmable-matched filter is set. The controller can generate a pilot-control signal to cause the match of the programmable-impulse response of the programmable-matched filter to that of the pilot-chip-sequence signal embedded in the received-spread-spectrum signal. The controller also can generate a data-control signal to cause the programmable-impulse response of the programmable-matched filter to be matched to the data-chip-sequence signal of the received spread-spectrum signal. Timing to the controller can be from the peak-pilot-correlation signal generated at the output of the frame-

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matched filter. Thus, in response to the peak-pilot-
correlation signal, using the data-control signal, the
controller can cause the programmable-matched filter to be
matched from the replica of the pilot-chip-sequence signal,

5          to the pilot-chip-sequence signal. At a time delay from the
peak-pilot-correlation signal, using the pilot-control
signal, the controller can cause the programmable-matched
filter to be matched from the replica of the data-chip-
sequence signal, to the data-chip-sequence signal embedded

10         in the received-spread-spectrum signal.

The present invention also includes a method for using
a programmable-matched filter and a frame-matched filter as
part of a spread-spectrum receiver on a received spread-
spectrum signal. As with the spread-spectrum-matched-filter

15         apparatus set forth above, the received spread-spectrum
signal is assumed to include a pilot-spread-spectrum channel
and a data-spread-spectrum channel. The pilot-spread-
spectrum channel is generated frcm spread-spectrum
processing a pilot-bit-sequence signal with a pilot-chip-

20         sequence signal. The data-spread-spectrum channel is
generated from spread-spectrum processing a data-bit-
sequence signal with a data-chip-sequence signal.

The steps include generating a replica of the pilot-
chip-sequence signal and a replica of the data-chip-sequence

25         signal, and programming, using the replica of the pilot-
chip-sequence signal and the replica of the data-chip-
sequence signal, the programmable-matched filter to have an
impulse response matched to either of the pilot-chip-

sequence signal or the data-chip-sequence signal,
respectively. When the programmable-matched filter is
matched to the pilot-chip-sequence signal, the method
includes the steps of despreading the pilot-spread-spectrum

5    signal from the received spread-spectrum signal as a
despread-pilot-bit-sequence signal, and filtering with the
frame-matched filter the despread-pilot-bit-sequence signal
and generating a peak-pilot-correlation signal.

When the programmable-matched filter is matched to the

10   data-chip-sequence signal, the steps include despreading the
data-spread-spectrum signal from the received spread-
spectrum signal as a despread-data-bit-sequence signal.

Additional objects and advantages of the invention are
set forth in part in the description which follows, and in

15   part are obvious from the description, or may be learned by
practice of the invention. The objects and advantages of
the invention also may be realized and attained by means of
the instrumentalities and combinations particularly pointed
out in the appended claims.


20   BRIEF DESCRIPTION OF THE DRAWINGS
The accompanying drawings, which are incorporated in
and constitute a part of the specification, illustrate
preferred embodiments of the invention, and together with
the description serve to explain the principles of the

25   invention.
FIG. 1 is a block diagram of a signal-time-sharing,
matched-filter-based demodulator;

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FIG. 2 illustrates a matched filter using time sharing of multiplier array and adder tree; and

FIG. 3 shows possible timing of signal-time-sharing, matched-filter-based demodulator.

5       DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference now is made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals indicate like elements throughout the
10      several views.

The present invention provides a new and novel spread-spectrum-matched-filter apparatus which can be used as part of a spread-spectrum receiver on a received spread-spectrum signal. The received spread-spectrum signal is assumed to
15      have a pilot-spread-spectrum channel and a data-spread-spectrum channel. The pilot-spread-spectrum channel is generated from spread-spectrum processing, by using techniques well known in the art, a pilot-bit-sequence signal with a pilot-chip-sequence signal. The pilot-bit-
20      sequence signal may be a constant level, i.e., just a series of 1-bits, or a series of 0-bits, or alternating 1-bits and 0-bits, or other sequence as desired. Typically, data are not sent with a pilot-bit-sequence signal. In some applications, data, preferably with a low data rate, may be
25      imposed on the pilot-bit-sequence signal. The pilot-chip-sequence signal is user defined, and in a usual practice, is used with a pilot-bit-sequence signal.

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The data-spread-spectrum channel is generated
similarly, from techniques well known in the art as used for
the pilot-spread-spectrum channel, by spread-spectrum
processing a data-bit-sequence signal with a data-chip-
5       sequence signal. The data-bit-sequence signal may be
derived from data, or analog signal converted to data, or
other source of data bits. The data-chip-sequence signal
can be user defined, and preferably is orthogonal to the
pilot-chip-sequence signal, as is well known in the art.

10          Broadly, the spread-spectrum-matched-filter apparatus
includes code means, programmable-matched means, frame-
matched means, control means, and demodulator means. The
control means is coupled to the code means and programmable-
matched means. The frame-matched means is coupled to the
15      output of the programmable-matched means. The demodulator
means is coupled to the output of the programmable-matched
means.

The code means generates a replica of the pilot-chip-
sequence signal and a replica of the data-chip-sequence
20      signal. These replicas of the pilot-chip-sequence signal
and the data-chip-sequence signal are the same sequences as
used for generating the received spread-spectrum signal
which arrives at the input of the spread-spectrum-matched-
filter apparatus. The code means can change over time the
25      particular chipping sequence from which the replica of the
pilot-chip-sequence signal and from which the replica of the
data-chip-sequence signal are generated. Accordingly, the
spread-spectrum-matched-filter apparatus can be used for a

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variety of pilot-chip-sequence signals and data-chip-
sequence signals as generated by the code means, as might be
used in a cellular-spread-spectrum architecture where a
receiver might move from one geographical area to another.

5        As the spread-spectrum-matched-filter apparatus moves from
one geographical area to another, by way of example, a
requirement might be imposed of having to change the pilot-
chip-sequence signal and the data-chip-sequence signal in
each of the different geographical areas.

10       The programmable-matched means has a programmable-
impulse response.  The programmable-impulse response can be
set from the replica of the pilot-chip-sequence signal
generated by the code means, and the replica of the data-
chip-sequence signal generated by the code means.  Thus, the

15   programmable-impulse response may be set for filtering from
the received spread-spectrum signal, the pilot-spread-
spectrum channel.  With the programmable-impulse response
set to the replica of the pilot-chip-sequence signal, and
with the pilot-spread-spectrum channel at the receiver, the

20   programmable-matched means outputs a despread-pilot-bit-
sequence signal.

         When the programmable-matched means has the
programmable-impulse response set from the replica of the
data-chip-sequence signal, then the programmable-matched

25   means filters from the received spread-spectrum signal, the
data-spread-spectrum channel.  Thus, the programmable-
matched means can output the despread-data-bit-sequence
signal.  Accordingly, the programmable-matched means can

despread cither of the pilot-spread-spectrum channel or the
data-spread-spectrum channel, depending on how the
programmable-impulse response is set. As set forth below,
the programmable-matched means changes dynamically, while
receiving the received spread-spectrum signal, allowing the
programmable-matched means to be time shared while receiving
the pilot-chip-sequence signal and the data-chip-sequence
signal.

The frame-matched means has a frame-impulse response
matched to the pilot-bit-sequence signal. Thus, the frame-
matched means filters the despread-pilot-bit-sequence signal
from the programmable-matched means, and generates as a
result thereof, a peak-pilot-correlation signal when the
despread-pilot-bit-sequence signal matches the frame-impulse
response. The frame-matched means may have a programmable-
frame-impulse response, which might change between different
geographical areas.

The control means controls the setting of the
programmable-impulse response of the programmable-matched
means. The control means can dynamically set the
programmable-matched means, by using the replica of the
pilot-chip-sequence signal generated by the code means, to
match the pilot-chip-sequence signal embedded in the
received spread-spectrum signal. Similarly, the control
means can dynamically set the programmable-matched means, by
using the replica of the data-chip-sequence signal generated
by the code means, to match the data-chip-sequence signal.
The control means can set the programmable-impulse response

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alternately, at various time delays, so that the
programmable-matched means alternately detects the pilot-
bit-sequence signal and the data-bit-sequence signal
embedded in the received-spread-spectrum signal.

5          The programmable-matched means may include an in-phase-
programmable-matched means and a quadrature-phase-
programmable-matched means.  The in-phase-programmable-
matched means has an in-phase-programmable-impulse response
which can be set from the replica of the pilot-chip-sequence
10         signal or the replica of the data-chip-sequence signal
generated by the code means.  Depending on which setting the
in-phase-programmable-matched means has, the in-phase-
programmable-matched means despreads from the received
spread-spectrum signal, an in-phase-component of the pilot-
15         spread-spectrum signal channel as a despread-in-phase-
component of the pilot-bit-sequence signal, or an in-phase
component of the data-spread-spectrum channel as a despread-
in-phase component of the data-bit-sequence signal.

The quadrature-phase-programmable-matched means has a
20         quadrature-impulse response which can be set from the
replica of the pilot-chip-sequence signal or the replica of
the data-chip-sequence signal generated by the code means.
When the quadrature-phase-programmable-matched means has the
quadrature-impulse response matched to the pilot-chip-
25         sequence signal, the quadrature-phase-programmable-matched
means despreads from the received spread-spectrum signal a
quadrature-phase component of the pilot-spread-spectrum
channel as a despread-quadrature-phase component of the

pilot-bit-sequence signal.  Similarly, when the quadrature-
phase-programmable-matched means has the quadrature-
programmable-impulse response set from the replica of the
data-chip-sequence signal, the quadrature-phase-

5       programmable-matched means despreads the received spread-
spectrum signal as a quadrature-component of the data-
spread-spectrum channel as a despread-quadrature-phase
component of the despread data-bit-sequence.

       In use, the control means has the in-phase-

10      programmable-matched means and the quadrature-phase-
programmable-matched means time synchronized so that they
are alternatively matched to detect the pilot-chip-sequence
signal or the data-chip-sequence signal.  This dynamic
changing of the in-phase-programmable-matched means and the

15      quadrature-phase-programmable-matched means is done
alternately during reception of a spread-spectrum signal,
time sharing these elements for detecting the pilot-chip-
sequence signal and the data-chip-sequence signal embedded
in the received spread-spectrum signal.  The frame-matched

20      means may include an in-phase-frame-matched means and a
quadrature-phase-frame-matched means.  The in-phase-frame-
matched means has an in-phase-frame-impulse response matched
to an in-phase component of the pilot-bit-sequence signal.
When the in-phase component of the despread-pilot-bit-

25      sequence signal from the in-phase-programmable-matched means
matches the in-phase-frame-impulse response, then an in-
phase-peak-pilot-correlation signal is generated.

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The quadrature-phase-frame-matched means has a quadrature-phase-frame-impulse response matched to a quadrature-phase component of the pilot-bit-sequence signal. When the quadrature-phase component of the despread-pilot-
5      bit-sequence signal matches the quadrature-phase-frame-impulse response of the quadrature-phase-frame-matched means, then a quadrature-phase-peak-pilot-correlation signal is generated.

In the exemplary arrangement shown in FIG. 1, the code
10     means is embodied as a code generator 43, the programmable-matched means is embodied as an in-phase-programmable-matched filter 35 and a quadrature-phase programmable-matched filter 37, the frame-matched means is embodied as an in-phase-frame-matched filter 38 and a quadrature-phase-
15     frame-matched filter 39, the control means is embodied as a controller 46, and the demodulator means is embodied as a demodulator 41.  The in-phase-programmable-matched filter 35 and the quadrature-phase-programmable-matched filter 37 may be constructed as digital-matched filters, surface-acoustic-
20     wave devices, or as software embedded in a processor or as an application specific integrated circuit (ASIC).  Also shown is a voltage controlled oscillator 45, timing generator 44, diversity combiner 42, frame processor 40, Costas loop 36 (or other generic tracking loop), in-phase
25     analog-to-digital converter 33, quadrature-phase analog-to-digital converter 34, in-phase mixer 31, and quadrature-phase mixer 32.  The in-phase analog-to-digital converter 33 is coupled between in-phase mixer 31 and in-phase-

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programmable-matched filter 35. The quadrature-phase analog-to-digital converter 34 is coupled between the quadrature-phase mixer 32 and the quadrature-phase-programmable-matched filter 37. The Costas loop 36 is

5    coupled to the output of the in-phase-programmable-matched filter 35, to the demodulator 41, and to the in-phase mixer 31 and the quadrature-phase mixer 32. The in-phase-frame-matched filter 38 is coupled between the in-phase-programmable-matched filter 35 and the frame processor 40

10   and the demodulator 41. The quadrature-phase-frame-matched filter 39 is coupled between the quadrature-phase-programmable-matched filter 37 and the processor 40 and the demodulator 41. The code generator 43 is coupled between timing generator 44 and to the in-phase-programmable-matched

15   filter 35 and the quadrature-phase-programmable-matched filter 37. The voltage controlled oscillator 45 is coupled to the timing generator 44 and to the matched-filter controller 46. The diversity combiner 42 is coupled to the frame processor 40 and the demodulator 41. The controller

20   46 is coupled to the frame processor 40. The prefixes "in-phase" and "quadrature-phase" denote that component, i.e., in-phase or quadrature-phase, of the received-spread-spectrum signal, with which the element operates.

For control, indicated by broken lines, the controller

25   46 is coupled to the diversity combiner 42, the frame-matched filter 38, the frame-matched filter 39, the demodulator 41, the timing generator 44, the code generator 43, the in-phase-analog-to-digital converter 33, and the

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quadrature-phase-analog-to-digital converter 34.

Referring to FIG. 1, a received spread-spectrum signal
at the signal input is translated to an intermediate
frequency or baseband frequency by in-phase mixer 31 and

5    quadrature-phase mixer 32.  For discussion purposes, the
received-spread-spectrum signal is assumed to be translated
to a baseband frequency.  Thus, the baseband received
spread-spectrum signal is converted to a digital signal by
in-phase analog-to-digital converter 33 and quadrature-phase

10   analog-to-digital converter 34.  Thus, a baseband version of
the received spread-spectrum signal is at the input of the
in-phase-programmable-matched filter 35 and the quadrature-
phase-programmable-matched filter 37.

The in-phase-programmable-matched filter 35 has an in-

15   phase-programmable-impulse response which is set by the
replica of the pilot-chip-sequence signal or the replica of
the data-chip-sequence signal from code generator 43.
Depending on the setting, the in-phase-programmable-matched
filter 35 can despread the received spread-spectrum signal

20   as a despread-in-phase component of the pilot-bit-sequence
signal or as a despread-in-phase component of the data-
spread-spectrum channel.  Accordingly, the in-phase-
programmable-matched filter 35 outputs either a despread-in-
phase component of the pilot-bit-sequence signal, or a

25   despread-in-phase component of the data-bit-sequence signal
as a despread-data-bit-sequence signal.

Similarly, the quadrature-phase-programmable-matched
filter 37 has a programmable-impulse response which can be

set by the replica of the pilot-chip-sequence signal or the
replica of the data-chip-sequence signal generated by the
code generator 43.  Depending on the setting, the
quadrature-phase-programmable-matched filter 37 despreads
the received spread-spectrum signal as a quadrature-phase
component of the pilot-spread-spectrum channel or as a
quadrature-phase component of the data-spread-spectrum
channel.  These can be either the despread-quadrature-phase-
pilot-bit-sequence signal or the quadrature-phase-data-bit-
sequence signal.

The in-phase-programmable-matched filter 35 and the
quadrature-phase-programmable-matched filter 37 are
ultimately controlled by the controller 46.  The controller
46 controls timing and determines at desired timings when
the code generator 43 sets the programmable-impulse
responses of the in-phase-programmable-matched filter 35 and
the quadrature-phase-programmable-matched filter 37 to the
respective pilot-chip-sequence signal or the data-chip-
sequence signal.

As shown in FIG. 2, the controller 46 controls the in-
phase signal register 51 and the quadrature-phase signal
register 52, which correspond to the in-phase-programmable-
matched filter 35 and the quadrature-phase-programmable-
matched filter 37, respectively.

In FIG. 1, the Costas loop 36 uses the output from the
in-phase-programmable-matched filter 35 and the quadrature-
phase-programmable-matched filter 37 to generate the cosine

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and sine signals for in-phase mixer 31 and quadrature-phase
mixer 32, respectively.

When the in-phase-programmable-matched filter 35 and
quadrature-phase-programmable-matched filter 37 have their
respective programmable-impulse responses matched to the
pilot-chip-sequence signal, then the output is a despread-
pilot-bit-sequence signal.  The despread-pilot-bit-sequence
signal is passed through in-phase-frame-matched filter 38
and quadrature-phase-frame-matched filter 39, respectively.
The in-phase-frame-matched filter 38 has an in-phase-frame-
impulse response matched to the in-phase component of the
pilot-bit-sequence signal, and accordingly, generates an in-
phase-peak-pilot correlation signal when the in-phase
component of the despread-pilot-bit-sequence signal matches
the in-phase-frame-impulse response.  Similarly, the
quadrature-phase-frame-matched filter 39 has a quadrature-
phase-frame-impulse response matched to a quadrature-phase
component of the pilot-bit-sequence signal.  When the
despread pilot-bit-sequence signal from the quadrature-
phase-programmable-matched filter 37 matches the quadrature-
phase-frame-impulse response of the quadrature-phase-matched
filter 37, then the quadrature-phase-frame-matched filter
outputs a quadrature-phase-peak-pilot-correlation signal.
The in-phase-peak-pilot-correlation signal and the
quadrature-phase-peak-pilot-correlation signal are
demodulated by demodulator 47, and can be used as a initial
timing signal for controlling when the diversity combiner 47
combines the output from the demodulator 41 for the

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respective signals from in-phase-programmable-matched filter

35 and the quadrature-phase-programmable-matched filter 37.

Additionally, the in-phase-peak-pilot-correlation

signal and the quadrature-phase-peak-pilot-correlation

5    signal can be processed by frame processor 40 to trigger a

timing signal to controller 46 which actuates the timing for

when a respective in-phase-programmable-impulse response and

the quadrature-phase-programmable-impulse response of the

in-phase-programmable-matched filter 35 and the quadrature-

10   phase-programmable-matched filter 37, respectively are

matched to either of the pilot-chip-sequence signal or the

data-chip-sequence signal.

In a particular implementation of the present

invention, the in-phase-programmable-matched filter 35 and

15   the quadrature-phase-programmable-matched filter 37 have

their respective in-phase-programmable-impulse response and

quadrature-phase-programmable-impulse response staggered,

under the control of the controller 46, such that they are

matched to the pilot-chip-sequence signal and then to the

20   data-chip-sequence signal every five microseconds.

Accordingly, each of the in-phase-programmable-matched

filter 35 and the quadrature-phase-programmable-matched

filter 37 can have their respective in-phase-programmable-

impulse response and quadrature-phase-programmable-impulse

25   response loaded within five microseconds.  Typically,

current designs have these respective programmable-matched

filters loaded within 2.5 microseconds, for a system

operating a 100 MHz, with each of the in-phase-programmable-

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matched filter 35 and the quadrature-phase-programmable-
matched filter 37 having a 250 stage shift register.

The demodulator 41 can be implemented using coherent
demodulation, or alternatively noncoherent demodulation.

5       The diversity combiner 42 combines in a variety of
ways, such as maximum likelihood, straight combining,
addition, or the demodulated outputs from the in-phase-
programmable-matched filter 35 and the quadrature-phase-
programmable-matched filter 37 as demodulated through

10      demodulator 41.

FIG. 2 illustrates the matched filter using the time
sharing of the multiplier array and adder tree.  Shown in
FIG. 2 are in-phase-signal register 51, quadrature-phase-
signal register 52, reference-signal register 53, multiplier

15      array 54, adder tree 55, data register 56, and controller
46.  As shown, the dotted lines indicate that the controller
46 provides the necessary controlling of the in-phase-signal
register 51, the quadrature-phase-signal register 52, the
reference-signal reference 53 and the data register 56.  The

20      solid lines indicate the signal flow from the in-phase-
signal register 51, the quadrature-phase-signal register 52,
the reference-signal register 53 through multiplexer 57.
The in-phase-signal register 51 and the quadrature-phase-
signal register 52 are coupled through multiplexer 57 to

25      multiplier array 54 to adder tree 55 to data register 56.
The data register 56 has the in-phase output and quadrature-
phase output.

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FIG. 3 illustrates block timing of the signal sharing, matched-filter-based correlator. As shown, a frame can begin every 8192 chips and a first signal, such as the pilot-chip-sequence signal can be output from the code

5      generator 43 every 256 chips. Similarly, a second signal, such as a data-chip-sequence signal can be output every 256 chips, but staggered from the first signal, i.e., the pilot signal. Thus, the in-phase-programmable-matched filter 35 and the quadrature-phase-programmable-matched filter 37 are

10     loaded with the first signal, the pilot-chip-sequence signal, and then staggered and loaded with the second signal, the data-chip-sequence signal. The first signal would represent loading the respective matched filters with the pilot-chip-sequence signal and the second signal would

15     be the timing for loading the respective matched filters with the data-chip-sequence signal.

The present invention also includes a method which uses a programmable-matched filter and a frame-matched filter with a spread-spectrum receiver on a received spread-

20     spectrum signal. As with the apparatus previously disclosed, the received spread-spectrum signal is assumed to have a pilot-spread-spectrum channel and a data-spread-spectrum channel. The pilot-spread-spectrum channel is generated from spread-spectrum processing a pilot-bit-

25     sequence signal with a pilot-chip-sequence signal. The data-spread-spectrum channel is generated from spread-spectrum processing a data-bit-sequence signal with a data-chip-sequence signal.

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The method comprises the steps of generating a replica of the pilot-chip-sequence signal and a replica of the data-chip-sequence signal. In response to the currents of a peak-pilot correlation signal, at an appropriate delay, the

5      method generates a pilot-control signal. In response to the pilot-control signal, the method programs the programmable-matched filter with the replica of the pilot-chip-sequence signal to set the programmable-matched filter to have a programmable-impulse response matched to the pilot-chip-

10     sequence signal. With the programmable-matched filter matched to the pilot-chip-sequence signal, the method despreads the pilot-spread-spectrum channel from the received spread-spectrum signal as a despread pilot-bit-sequence signal.

15     The frame-matched filter has a frame-impulse response matched to the pilot-bit-sequence signal. The method therefore uses the frame-matched filter to filter the despread pilot-bit-sequence signal. The method thereafter generates from the filtered despread-pilot-bit-sequence

20     signal, the peak-pilot-correlation signal in response to the despread-pilot-bit-sequence signal matching the frame-impulse response of the frame-matched filter.

The method also generates at a time delay from the pilot-control signal, and in response to the peak-pilot-

25     correlation signal, a data-control signal. In response to the data-control signal, the method programs the programmable-matched filter with the replica of the data-chip-sequence signal so that the programmable-matched filter

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has the programmable-impulse response matched to the data-
chip-sequence signal.  The method thereby despreads, while
the programmable-matched filter is matched to the data-chip-
sequence signal, the data-spread-spectrum channel from the

5       received spread-spectrum signal as a despread-data-bit-
sequence signal.

The method as described herein may be extended to in-
phase and quadrature-phase components of a received-spread-
spectrum signal.  As such, the method would have the step of

10      despreading the pilot-spread-spectrum channel from the
received spread-spectrum signal including the steps of
despreading, from the received spread-spectrum signal, the
in-phase component of the pilot-spread-spectrum channel as a
despread in-phase component of the pilot-bit-sequence

15      signal, and despreading, from the received spread-spectrum
signal, the quadrature-phase component of the pilot-spread-
spectrum channel as a despread-quadrature-phase component of
the pilot-bit-sequence signal.

Similarly, the in-phase component and the quadrature-

20      phase component of the received-spread-spectrum signal can
be despread as in-phase components and quadrature-phase
components of the data-spread-spectrum channel.
Accordingly, the method would include despreading, from the
received spread-spectrum signal, an in-phase component of

25      the data-spread-spectrum channel as a despread-in-phase
component of the despread-data-bit-sequence signal.  The
method would also include despreading, a quadrature-phase
component of the data-spread-spectrum channel as a despread-

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quadrature-phase component of the despread-data-bit-sequence
signal.

When filtering the despread pilot-bit-sequence signal
into in-phase components and quadrature-phase components of
5       the despread-pilot-bit-sequence signal, the method can also
include generating an in-phase-peak-pilot-correlation signal
and a quadrature-phase-peak-pilot-correlation signal, in
response to the in-phase component and the quadrature-phase
component of the despread pilot-bit-sequence signal matching
10      the in-phase-frame-impulse response and the quadrature-
phase-frame-impulse response, respectively.

In operation the in-phase-programmable-matched filter
35 and the quadrature-phase-programmable-matched filter 37
are loaded with M local sequence symbols, i.e., either the
15      replica of the pilot-chip-sequence signal or the replica of
the data-chip-sequence signal.  The incoming received
spread-spectrum signal samples generated by in-phase-analog-
to-digital converter 33 and quadrature-phase-analog-to-
digital converter 34, respectively, slide by, i.e. are
20      correlated against, the local replicas until they line up,
at which time a large information bearing output is
produced.  The generation of this large output does not
require that a synchronization process be successfully
completed a priori or that additional circuits dedicated to
25      the acquisition process be employed and it achieves code
synchronization in the shortest possible time to acquire the
incoming spreading chip-sequence signal.  This has the
advantage of lower implementation cost, lower physical

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volume, less power consumption, more rapid implementation
and much better performance as measured by the time required
to achieve code synchronization.

The presence of a strong signal level output indicates

5       that at that specific moment in time M incoming signal
symbols and the M symbols of the local spreading code, i.e.
chip-sequence signal, loaded in the in-phase-programmable-
matched filter 35 and the quadrature-phase-programmable-
matched filter 37 are in alignment.  The requirement exists

10      that the in-phase-programmable-matched filter 35 and the
quadrature-phase-programmable-matched filter 37 be fully
loaded with the next M symbols of the local spreading code,
the pilot-chip-sequence signal or the data-chip-sequence
signal at any time prior to the arrival of the next M

15      incoming signal symbols at the in-phase-programmable-matched
filter 35 and the quadrature-phase-programmable-matched
filter 37.  The value of the number M, which denotes the
size of the respective programmable-matched filter as
measured in number of signal samples, is much larger than

20      any value on the order of one; in the present embodiment M
is on the order of 250.  Because M is much larger than one
the circuits required to implement the code phase
synchronization functions are much easier to design and
implement.  This has the advantage of lower implementation

25      cost, lower physical volume, less power consumption, more
rapid implementation and inherently better performance.

The in-phase-programmable-matched filter 35 and the
quadrature-phase-programmable filter 37 identify,

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characterize and extract the information which arrives
through all available channels, or paths, intrinsically
without any additional and parallel signal processing paths.
The spreading code loaded as a local reference in the in-
5      phase-programmable-matched filter 35 and the quadrature-
phase-programmable-matched filter 37 remain in place until
all propagation channels have the opportunity to deliver the
information signal at the in-phase-programmable-matched
filter 35 and the quadrature-phase-programmable-matched
10     filter 37; the matched filter can then easily recover all
$L=T_M(W+1)$ signals it is capable of receiving.  As the input
signals are offset in time due to differences in length of
the propagation path, and since the in-phase-programmable-
matched filter 35 and the quadrature-phase-programmable-
15     matched filter 37 are linear devices, the outputs due to the
signals propagation through different channels are output by
the in-phase-programmable-matched filter 35 and the
quadrature-phase-programmable-matched filter 37 offset in
time.  Thus the reception and separation of the signals
20     propagating through different channels does not require any
additional circuits and the individual signals, which are
now separate in time can be easily individually manipulated
and combined in optimum ways such that the matched filter
receiver attains the performance of a L-diversity system.
25         A receiver capable of identifying, separating and
combining large numbers (L) of signal replicas propagating
through different channels is referred to as a RAKE
receiver.  The RAKE receiver structure is optimal and the

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matched filter can implement it without the excessive

complexity incurred by alternative system implementations.

The in-phase-programmable-matched filter 35 and the

quadrature-phase-programmable-matched filter 37

5      implementation of the heart of the diversity processing

system has the advantage of lower implementation cost, lower

physical volume, less power consumption, more rapid

implementation, less complex control and better performance.

In contrast, the programmable-matched-filter-based

10     demodulator as described herein utilizes only one such set

of circuits and, using information which is intrinsically

generated, can then coherently demodulate any number of

signal replicas, including all $L=T_M(W+1)$, that arrive via

separate propagation paths. The mechanism by which this is

15     accomplished is to employ one conventional phase tracking

circuit, e.g., phase-locked loop (PLLs), Costas loop 36, or

$n^{th}$ power loop, in order to establish a temporarily stable

phase reference and then extract the phase offset of each

individual signal with respect to that phase reference. The

20     incoming signal is first downconverted non-coherently to

some frequency, including the 0 Hz frequency (DC). Then the

in-phase and quadrature-phase channel outputs are read from

the in-phase-programmable-matched filter 35 and the

quadrature-phase-programmable-matched filter 37,

25     respectively. The phase offset of the carrier signal is

contained in the relative amplitudes of the in-phase and

quadrature-phase outputs which are then used directly to

demodulate the received data signal in a differential mode.

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Alternatively the phase estimate on the individual
propagation paths can be improved by further matched
filtering to demodulate the signal with performance equal to
or better than that obtained using conventional coherent
5       demodulators but without the added complexity introduced by
conventional coherent demodulators.  Therefore the
programmable-matched filter-based implementation has the
advantage of much lower complexity, lower implementation
cost, lower physical volume, less power consumption, more
10      rapid implementation and better performance.

        A set of multipliers and the associated adder tree may
be eliminated.  By inputting the signals at the input of the
remaining set of multipliers and the associated adder tree
from two multiplexers, each multiplexer may serve to connect
15      to the multiplier/adder tree structure either the in-phase
or quadrature-phase signal registers.  This implementation
adds the complexity of two multiplexers and reduces the
complexity associated with a set of multipliers and an adder
tree for a significant net reduction in complexity.

20      The programmable-matched filter is a digital signal
processor, the output of which is of interest only at that
instant of time when the portion of interest of the incoming
signal is fully loaded and is of no interest at any other
time.  In the present implementation the size of the
25      programmable-matched filters is approximately 250 stages and
it requires 250 clock cycles to load the input samples of
the received spread-spectrum signal.  Its output is of
interest only for one or two clock cycles and is of no

interest for the rest of approximately 248 clock cycles.
Thus the circuit can be reused during these 248 clock
cycles. Two or more signals, say N signals, can utilize the
same matched filter provided that the signals are not lined
up in phase and thus the outputs are staggered in time. If
N=5 signals must share the same matched filter, the signals
could then be staggered by approximately 45 clock cycles and
the matched filter could be operated in a number of ways,
including the following manner:

1.     Starting at clock cycle 5, the programmable-
matched filters are loaded with the reference corresponding
to the first signal. The output due to the first signal
will occur during the $50^{th}$ and $51^{st}$ clock cycle.

2.     Starting at clock cycle 55, the programmable-
matched filters are loaded with the reference corresponding
to the second signal. The output due to the second signal
will occur during the $100^{th}$ and $101^{st}$ clock cycle.

3.     Starting at clock cycle 105, the
programmable-matched filters are loaded with the reference
corresponding to the third signal. The output to the third
signal will occur during the $150^{th}$ and $151^{st}$ clock cycle.

4.     Starting at clock cycle 155, the
programmable-matched filters are loaded with the reference
corresponding to the fourth signal. The output due to the
fourth signal will occur during the $200^{th}$ and $201^{st}$ clock
cycle.

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5.    Starting at clock cycle 205, the
programmable-matched filters are loaded with the reference
corresponding to the fifth signal.  The output due to the
fifth signal will occur during the $250^{th}$ and $251^{st}$ clock
cycle.

The cycle then repeats itself for the next output due
to the first, second, third, fourth and fifth signals using
only one matched filter.  The complexity of and size of
implementation is reduced by 80% while the signal processing
benefits remain constant.

It will be apparent to those skilled in the art that
various modifications can be made to the spread-spectrum-
matched-filter apparatus of the instant invention without
departing from the scope or spirit of the invention, and it
is intended that the present invention cover modifications
and variations of the spread-spectrum-matched-filter
apparatus provided they come within the scope of the
appended claims and their equivalents.

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<u>I CLAIM</u>:

1.    A spread-spectrum-matched-filter apparatus, for
use as part of a spread-spectrum receiver on a received
spread-spectrum signal having a pilot-spread-spectrum
channel generated from spread-spectrum processing a pilot-
bit-sequence signal with a pilot-chip-sequence signal and a
data-spread-spectrum channel generated from spread-spectrum
processing a data-bit-sequence signal with a data-chip-
sequence signal, comprising:

        code means for generating a replica of the pilot-
chip-sequence signal and a replica of the data-chip-sequence
signal;

        programmable-matched means, responsive to having a
programmable-impulse response set from the replica of the
pilot-chip-sequence signal, for filtering from the received
spread-spectrum signal, the pilot-spread-spectrum channel
thereby outputted as a despread-pilot-bit-sequence signal
and, responsive to having the programmable-impulse response
set from the replica of the data-chip-sequence signal, for
filtering from the received spread-spectrum signal, the
data-spread-spectrum channel thereby outputted as a despread
data-bit-sequence signal;

        frame-matched means having a frame-impulse
response matched to the pilot-bit-sequence signal for
filtering the despread-pilot-bit-sequence signal and
generating a peak-pilot-correlation signal in response to
the despread-pilot-bit-sequence signal matching the frame-
impulse response; and

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control means, coupled to said programmable-
matched means and said code means, responsive to the peak-
pilot-correlation signal, for setting, at a first time delay
from the peak-pilot-correlation signal, said programmable-
matched means with the replica of the pilot-chip-sequence
signal for matching said programmable-matched means to the
pilot-chip-sequence signal, and responsive to the peak-
pilot-correlation signal, for setting, at a second time
delay from the peak-pilot-correlation signal, said
programmable-matched means with the replica of the data-
chip-sequence signal for matching said programmable-matched
means to the data-chip-sequence signal.

2.    The spread-spectrum-matched-filter apparatus as
set forth in claim 1 wherein said programmable-matched means
includes:

in-phase-programmable-matched means, coupled to
said code means, responsive to having an in-phase-
programmable-impulse response set from the replica of the
pilot-chip-sequence signal generated by said code means, for
despreading from the received spread-spectrum signal, an in-
phase component of the pilot-spread-spectrum channel as a
despread-in-phase component of the pilot-bit-sequence
signal, and responsive to having the in-phase-programmable-
impulse response set from the replica of the data-chip-
sequence signal generated by said code means, for
despreading from the received spread-spectrum signal, an in-
phase component of the data-spread-spectrum channel as a

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despread-in-phase component of the despread-data-bit-
sequence signal; and

quadrature-phase-programmable-matched means,
coupled to said code means, responsive to having a
20    quadrature-programmable-impulse response set from the
replica of the pilot-chip-sequence signal generated by said
code means, for despreading from the received spread-
spectrum signal, a quadrature-phase component of the pilot-
spread-spectrum channel as a despread-quadrature-phase
25    component of the pilot-bit-sequence signal, and responsive
to having the quadrature-programmable-impulse response set
from the replica of the data-chip-sequence signal generated
by said code means, for despreading from the received
spread-spectrum signal, a quadrature-phase component of the
30    data-spread-spectrum channel as a despread-quadrature-phase
component of the despread-data-bit-sequence signal.


3.    The spread-spectrum-matched-filter apparatus as
set forth in claim 2 wherein said frame-matched means
includes:

in-phase-frame-matched means having an in-phase-
5     frame-impulse response matched to an in-phase component of
the pilot-bit-sequence signal for generating an in-phase
peak-pilot-correlation signal in response to the in-phase
component of the despread-pilot-bit-sequence signal matching
the in-phase-frame-impulse response; and
10    quadrature-phase-frame-matched means having a
quadrature-phase-frame-impulse response matched to a

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quadrature-phase component of the pilot-bit-sequence signal

for generating a quadrature-phase peak-pilot-correlation

signal in response to the quadrature-phase component of the

15    despread-pilot-bit sequence signal matching the quadrature-

phase-frame-impulse response.


4.    The spread-spectrum-matched-filter apparatus as

set forth in claim 1, further including demodulator means,

coupled to said programmable-matched means, for demodulating

the despread-data-bit-sequence signal as a received data-

5     bit-sequence signal.


5.    The spread-spectrum-matched-filter apparatus as

set forth in claim 2 or 3 further including demodulator

means, coupled to said in-phase-programmable-matched means

and to said quadrature-phase-programmable-matched means, for

5     demodulating the despread-in-phase component of the

despread-data-bit-sequence signal and the despread-

quadrature-phase component of the despread-data-bit-sequence

signal, as a received-data-bit-sequence signal.


6.    The spread-spectrum-matched-filter apparatus as

set forth in claim 1 or 4 wherein:

said programmable-matched means includes a

programmable-digital-matched filter having the programmable-

5     impulse response set by the replica of the pilot-chip-

sequence signal and the replica of the data-chip-sequence

signal; and

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said frame-matched means includes a frame-digital-matched filter having the frame-impulse response matched to

10          the pilot-bit-sequence signal.


7.      The spread-spectrum-matched-filter apparatus as set forth in claim 2 wherein:

said in-phase-programmable-matched means includes an in-phase-programmable-digital-matched filter having the

5          in-phase-programmable-impulse response set by the replica of the pilot-chip-sequence signal and the replica of the data-chip-sequence signal;

said quadrature-phase-programmable-matched means includes a quadrature-phase-programmable-digital-matched

10          filter having the quadrature-phase-impulse response set by the replica of the pilot-chip-sequence signal and the replica of the data-chip-sequence signal.


8.      The spread-spectrum-matched-filter apparatus as set forth in claim 3 wherein:

said in-phase-frame-matched means includes an in-phase-frame-digital-matched filter having the in-phase-

5          frame-impulse response matched to the in-phase component of the pilot-bit-sequence signal; and

said quadrature-phase-frame-matched means includes a quadrature-phase-frame-digital-matched filter having the quadrature-phase-impulse response matched to the quadrature-

10          phase component of the pilot-bit-sequence signal.

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9.    A method, using a programmable-matched filter and
a frame-matched filter with a spread-spectrum receiver on a
received spread-spectrum signal, the received spread-
spectrum signal having a pilot-spread-spectrum channel
5       generated from spread-spectrum processing a pilot-bit-
sequence signal with a pilot-chip-sequence signal and a data
spread-spectrum channel generated from spread-spectrum
processing a data-bit-sequence signal with a data-chip-
sequence signal, comprising the steps of:
10              generating a replica of the pilot-chip-sequence
signal;
                generating a replica of the data-chip-sequence
signal;
                generating, responsive to a peak-pilot correlation
15      signal, a pilot-control signal;
                programming said programmable-matched filter,
responsive to the pilot-control signal and using the replica
of ·the pilot-chip-sequence signal, to set said programmable-
matched filter to having a programmable-impulse response
20      matched to the pilot-chip-sequence signal;
                despreading, with the programmable-matched filter
matched to the pilot-chip-sequence signal, the pilot-spread-
spectrum channel from the received spread-spectrum signal as
a despread-pilot-bit-sequence signal;
25              filtering, with said frame-matched filter having a
frame-impulse response matched to the pilot-bit-sequence
signal, the despread-pilot-bit-sequence signal;

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generating from the filtered despread-pilot-bit-sequence signal, the peak-pilot-correlation signal in
30      response to the despread-pilot-bit-sequence signal matching the frame-impulse response of the frame-matched filter;

generating, responsive to the peak-pilot-correlation signal, at a time delay from the pilot-control signal, a data-control signal;

35      programming said programmable matched filter, responsive to the data-control signal and using the replica of the data-chip-sequence signal, to have the programmable-impulse response matched to the data-chip-sequence signal; and

40      despreading, with the programmable-matched filter matched to the data-chip-sequence signal, the data-spread-spectrum channel from the received spread-spectrum signal as a despread-data-bit-sequence signal.

10.   The method as set forth in claim 9, with the step of despreading the pilot-spread-spectrum channel from the received spread-spectrum signal further including the steps of:

5       despreading, from the received spread-spectrum signal, an in-phase component of the pilot-spread-spectrum channel as a despread-in-phase component of the despread-pilot-bit-sequence signal; and

despreading, from the received spread-spectrum
10      signal, a quadrature-phase component of the pilot-spread-

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spectrum channel as a despread-quadrature-phase component of the despread-pilot-bit-sequence signal.

11.  The method as set forth in claim 9 or 10 with the step of despreading the data-spread-spectrum channel further including the steps of:

despreading, from the received spread-spectrum
5      signal, an in-phase component of the data-spread-spectrum channel as a despread-in-phase component of the despread-data-bit-sequence signal; and

despreading, from the received spread-spectrum signal, a quadrature-phase component of the data-spread-
10     spectrum channel as a despread-quadrature-phase component of the despread-data-bit-sequence signal.

12.  The method as set forth in claim 10 with the step of filtering the despread pilot-bit-sequence signal further including the steps of:

generating an in-phase-peak-pilot-correlation
5      signal in response to the despread-in-phase component of the despread-pilot-bit-sequence signal matching an in-phase-frame-impulse response; and

generating a quadrature-phase peak-pilot-correlation signal in response to the despread-quadrature-
10     phase component of the despread-pilot-bit sequence signal matching a quadrature-phase-frame-impulse response.

13.   The method as set forth in claim 9, further
including the step of demodulating the despread-data-bit-
sequence signal as a received data-bit-sequence signal.


14.   The method as set forth in claim 10 further
including the step of demodulating an in-phase component of
the despread-data-bit-sequence signal and a quadrature-phase
component of the despread-data-bit-sequence signal, as a
5       received-data-bit-sequence signal.


15.   A spread-spectrum-matched-filter apparatus, for
use with a spread-spectrum receiver on a received spread-
spectrum signal having, a pilot-spread-spectrum channel
generated from spread-spectrum processing a pilot-bit-
5       sequence signal with a pilot-chip-sequence signal and a data
spread-spectrum channel generated from spread-spectrum
processing a data-bit-sequence signal with a data-chip-
sequence signal, comprising:

a code generator for generating a replica of the
10      pilot chip-sequence signal and a replica of the data-chip-
sequence signal;

programmable-matched means responsive to having a
programmable-impulse response set from the replica of the
pilot-chip-sequence, for filtering from the received spread-
15      spectrum signal, the pilot-spread-spectrum channel, to
output a despread-pilot-bit-sequence signal and, responsive
to having the programmable-impulse response set from the
replica of the data-chip-sequence signal, for filtering from

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the received spread-spectrum signal, the data-spread-

20    spectrum channel to output a despread-data-bit-sequence

signal;

a frame-matched filter having a frame-impulse

response matched to the pilot-bit-sequence signal for

filtering the despread-pilot-bit-sequence signal and

25    generating a peak-pilot-correlation signal in response to

the despread-pilot-bit-sequence signal matching the frame-

impulse response; and

a controller, coupled to said programmable-matched

means and said code generator, responsive to the peak-pilot-

30    correlation signal, for setting, from said code generator,

said programmable-matched means with the replica of the

pilot-chip-sequence signal for matching said programmable-

matched means to the pilot-chip-sequence signal and,

responsive to the peak-pilot-correlation signal, for setting

35    at a time delay from the peak-pilot-correlation signal from

said code generator, said programmable-matched means with

the replica of the data-chip-sequence signal for matching

said programmable-matched means to the data-chip-sequence

signal.


16.    The spread-spectrum-matched-filter apparatus as

set forth in claim 15 with said programmable-matched means

further including:

an in-phase-programmable-digital-matched filter,

5      coupled to said code generator, responsive to the replica of

the pilot-chip-sequence signal generated by said code

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generator for despreading from the received spread-spectrum

signal, an in-phase component of the pilot-spread-spectrum

channel as a despread in-phase component of the pilot-bit-

10      sequence signal, and responsive to the replica of the data-

chip-sequence signal generated by said code generator for

despreading from the received spread-spectrum signal, an in-

phase component of the data-spread-spectrum channel as a

despread-in-phase component of the despread-data-bit-

15      sequence signal; and

a quadrature-phase-programmable-digital-matched

filter, coupled to said code generator, responsive to the

replica of the pilot-chip-sequence signal generated by said

code generator for despreading from the received spread-

20      spectrum signal, a quadrature-phase component of the pilot-

spread-spectrum channel as a despread quadrature-phase

component of the pilot-bit-sequence signal, and responsive

to the replica of the data-chip-sequence signal generated by

said code generator for despreading from the received

25      spread-spectrum signal, a quadrature-phase component of the

data-spread-spectrum channel as a despread-quadrature-phase

component of the despread-data-bit-sequence signal.


17.    The spread-spectrum-matched-filter apparatus as

set forth in claim 16 wherein said frame-matched filter

includes:

an in-phase-frame-digital-matched filter having an

5       in-phase impulse response matched to an in-phase component

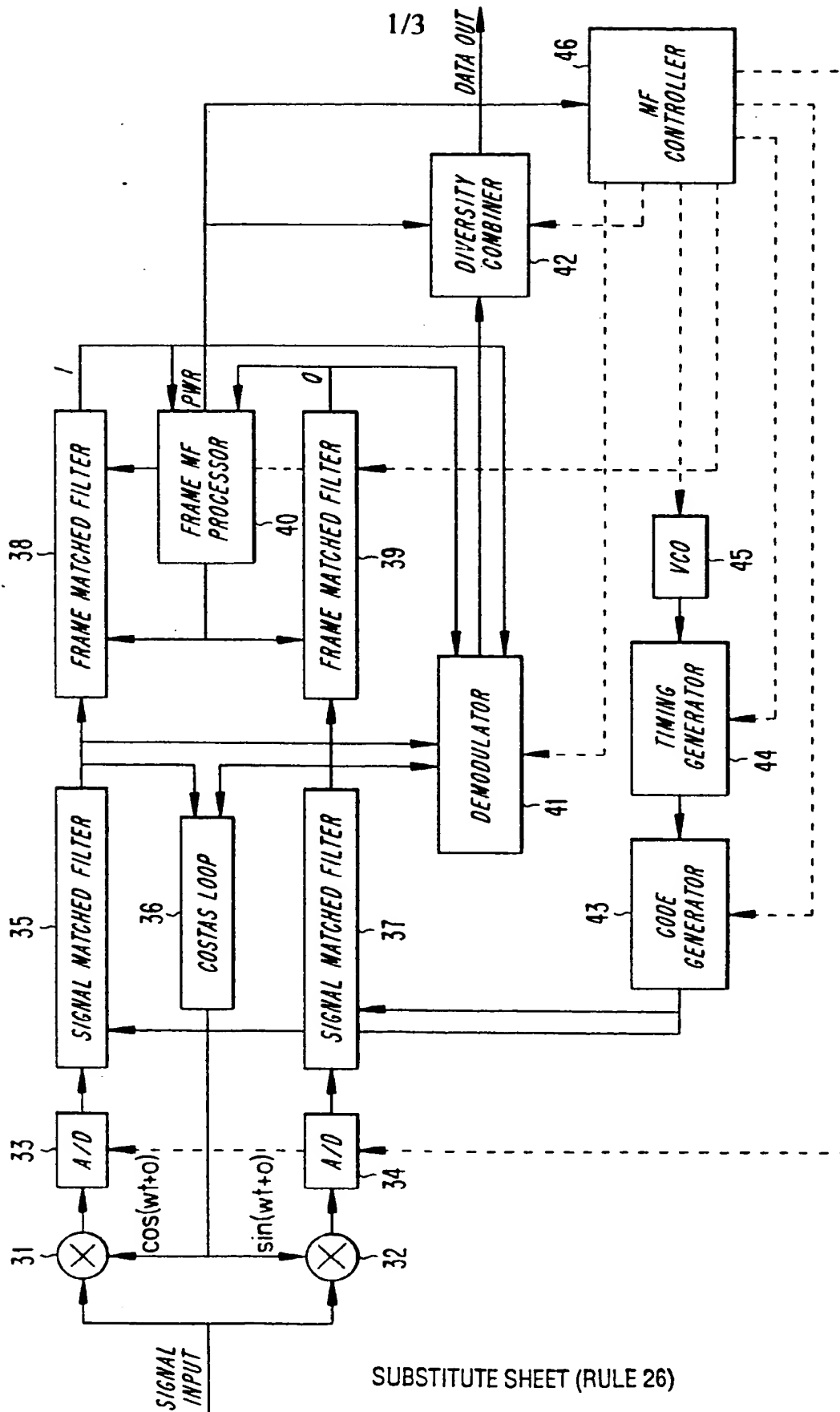of the pilot-bit-sequence signal for generating an in-phase

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peak-pilot-correlation signal in response to the in-phase
component of the despread-pilot-bit sequence signal matching
the in-phase impulse response; and

10          a quadrature-phase-frame-digital-matched filter
having a quadrature-phase impulse response matched to a
quadrature-phase component of the pilot-bit-sequence signal
for generating a quadrature-phase peak-pilot-correlation
signal in response to the quadrature-phase component of the
15    despread-pilot-bit sequence signal matching the quadrature-
phase impulse response.


18.     The spread-spectrum-matched-filter apparatus as
set forth in claim 15, 16 or 17, further including a
demodulator, coupled to said programmable-matched means, for
demodulating the despread-data-bit-sequence signal as a
5     received data-bit-sequence signal.


19.     The spread-spectrum-matched-filter apparatus as
set forth in claim 16 or 17 further including a demodulator,
coupled to said in-phase-programmable-digital-matched filter
and to said quadrature-phase-programmable-digital-matched
5     filter, for demodulating the despread-in-phase component of
the despread-data-bit-sequence signal and the despread-
quadrature-phase component of the despread-data-bit-sequence
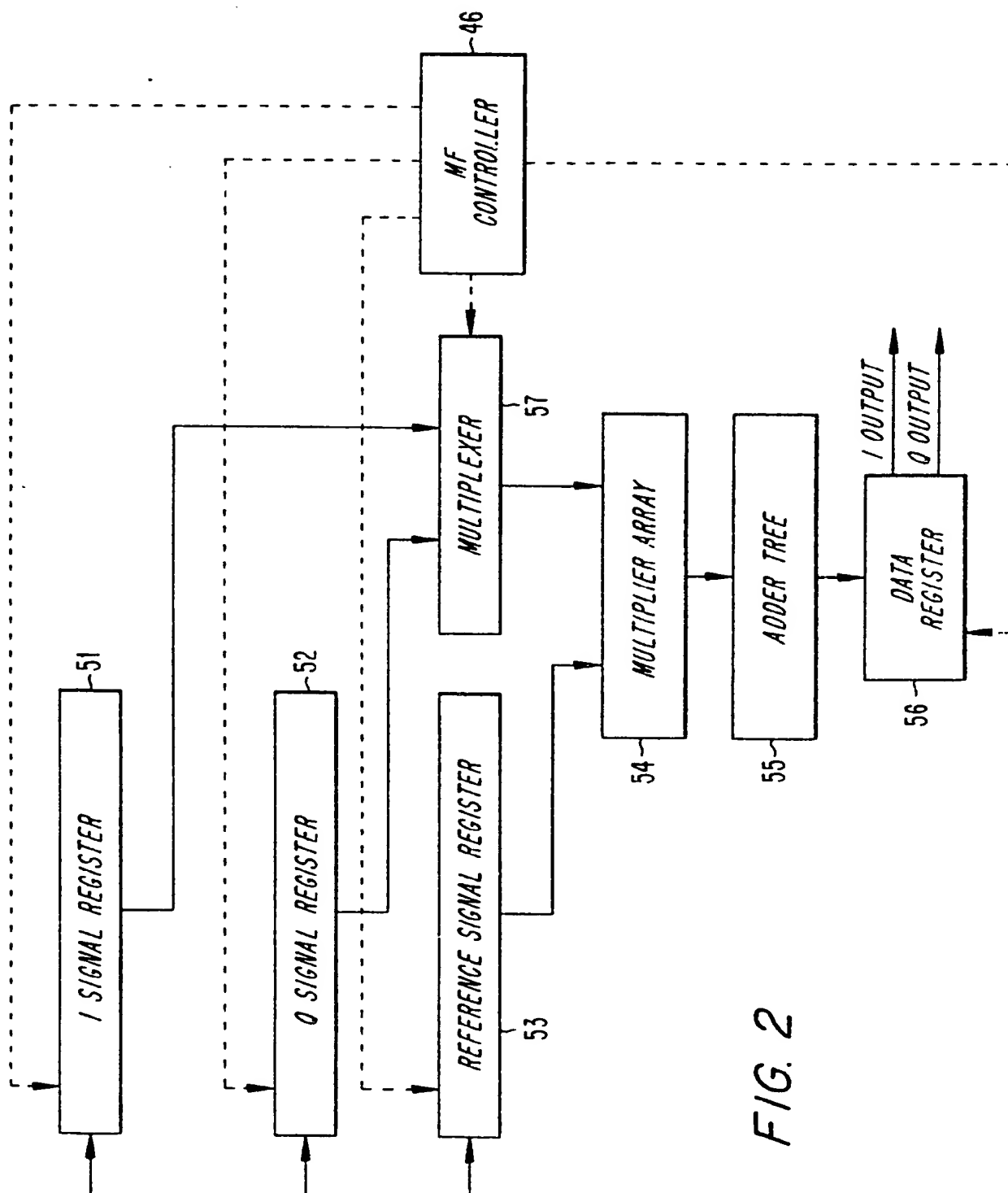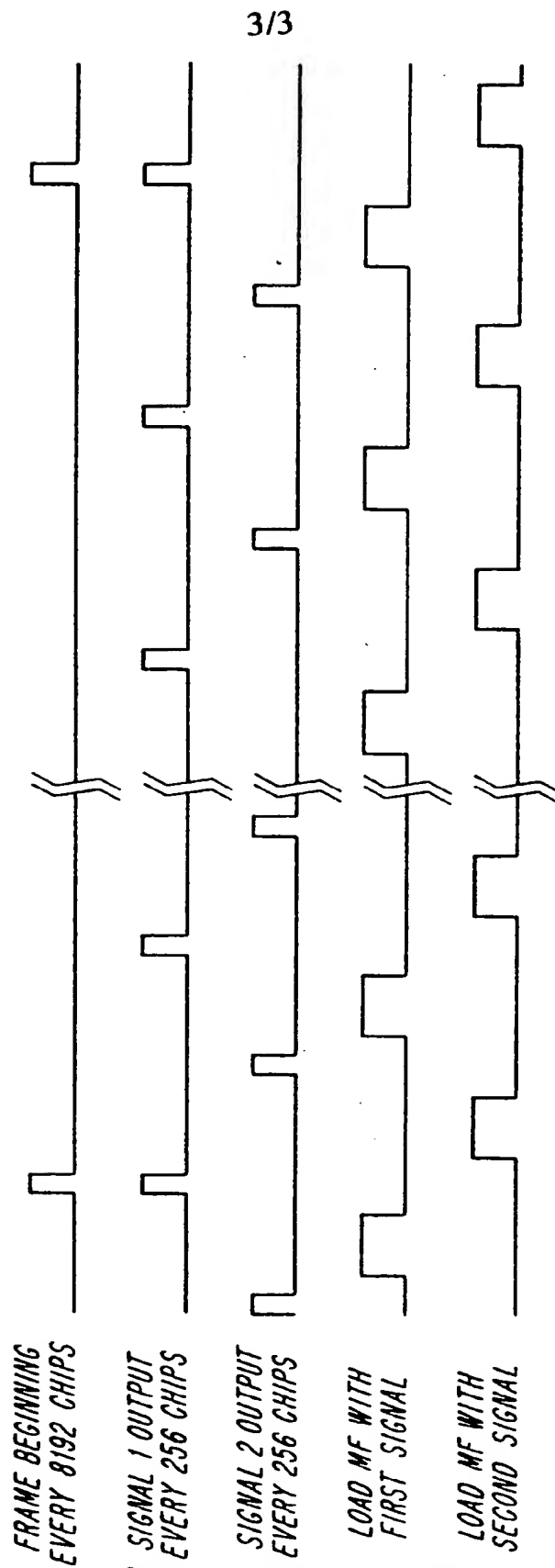signal as a received-data-bit-sequence signal.

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FIG. 1

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FIG. 2

# FIG. 3



FRAME BEGINNING
EVERY 8192 CHIPS

SIGNAL 1 OUTPUT
EVERY 256 CHIPS

SIGNAL 2 OUTPUT
EVERY 256 CHIPS

LOAD MF WITH
FIRST SIGNAL

LOAD MF WITH
SECOND SIGNAL

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :H04B 1/707

US CL : 375/207, 343

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/207, 343, 206, 724.11

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, STN

search terms: matched filtering, programmable, pseudonoise, pseudorandom, direct sequence

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US, A, 4,583,048 (GUMACOS ET AL) 15 April 1986, especially Figure 6b and its accompanying discussion. | 1-19 |
| Y | US, A, 4,630,283 (SCHIFF) 16 December 1986, especially Figure 5. | 1-19 |
| Y | US, A, 4,672,658 (KAVEHRAD ET AL) 09 June 1987, especially the abstract. | 1-19 |
| Y | US, A, 4,691,326 (TSUCHIYA) 01 September 1987, especially the abstract and figures. | 1-19 |
| Y | US, A, 4,755,983 (MASAK ET AL) 05 July 1988, especially the abstract. | 1-19 |
| Y | US, A, 5,031,192 (CLARK) 09 July 1991, especially Figure 17b. | 1-19 |

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

| * | Special categories of cited documents: | "T" | later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
|---|---|---|---|
| "A" | document defining the general state of the art which is not considered to be part of particular relevance | | |
| "E" | earlier document published on or after the international filing date | "X" | document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone |
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| "O" | document referring to an oral disclosure, use, exhibition or other means | | |
| "P" | document published prior to the international filing date but later than the priority date claimed | "&" | document member of the same patent family |

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 23 JULY 1996 | 16.08.96 |

| Name and mailing address of the ISA/US | Authorized officer |
|---|---|
| Commissioner of Patents and Trademarks<br>Box PCT<br>Washington, D.C. 20231 | JEFFREY W. GLUCK |
| Facsimile No. (703) 305-3230 | Telephone No. (703) 308-5462 |

Form PCT/ISA/210 (second sheet)(July 1992)*

| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT | | |
|---|---|---|
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| Y | US, A, 5,311,544 (PARK ET AL) 10 May 1994, especially Figure 2. | 1-19 |
| Y | Proceedings of the IEEE, Volume 64, No. 5, issued May 1976, J.H. Cafarella et al., "Acoustoelectric Convolvers for Programmable Matched Filtering in Spread-Spectrum Systems," pages 756-9, especially the abstract and first section. | 1-19 |